mum longitudinal length of the piezoelectric ceramic fibers provides maximum power generation and harvesting.

[0031] According to another aspect of the invention, the piezoelectric ceramic fibers may be positioned and oriented having a maximum number and concentration, wherein the maximum number and concentration of the piezoelectric ceramic fibers provides maximum power generation and harvesting.

[0032] According to another aspect of the invention, the piezoelectric ceramic fibers may be oriented in parallel array with a poling direction of the fibers being in the same direction.

[0033] According to another aspect of the invention, adjacent piezoelectric ceramic fibers may be in contact with one another.

[0034] According to another aspect of the invention, the piezoelectric ceramic fibers may be oriented in a star array having a center and individual fibers extending outward from the center. A poling direction of the fibers may be toward the center of the star array.

[0035] In another embodiment of the invention, a self-powered, portable electronic device includes: a housing; ultra low power electronics housed within the housing; and high charge piezoelectric ceramic fibers and/or fiber composites for harvesting increased deliverable power from mechanical inputs to the portable electronic device. The piezoelectric ceramic fibers and/or fiber composites being electrically coupled to the ultra low power electronics to power the ultra low power electronics. The integration and convergence of ultra low power electronics and high charge piezoelectric ceramic fibers and/or fiber composites enable the self-powered, portable electronic device.

[0036] In another embodiment of the invention, a method of self-powering a portable electronic device is disclosed. The method includes: incorporating an energy harvesting system comprising piezoelectric ceramic fibers into a portable electronic device; positioning and orienting the piezoelectric ceramic fibers at one or more mechanical energy input points; generating a charge in the piezoelectric ceramic fibers from mechanical energy input at the mechanical energy input points, wherein the mechanical energy is input through normal use of the portable electronic device; collecting the charge from the piezoelectric ceramic fibers using electrical circuitry; storing the charge from the piezoelectric ceramic fibers in an energy storage device; and powering one or more loads of the portable electronic device using the stored energy generated using the piezoelectric ceramic fibers.

[0037] Additional features and advantages of the invention will be made apparent from the following detailed description of illustrative embodiments that proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The invention is best understood from the following detailed description when read in connection with the accompanying drawings. Included in the drawings are the following Figures that show various exemplary embodiments and various features of the present invention:

[0039] FIG. **1** is a block diagram of an exemplary piezoelectric ceramic material energy harvesting system that may be used to self-power a powered portable electronic device;

[0040] FIG. **2**A is a front view of an exemplary self-powered portable electronic device having piezoelectric ceramic fibers to harvest mechanical energy in the closed position;

[0041] FIG. **2**B is a view of the exemplary self-powered portable electronic device of FIG. **2**A in the open position;

[0042] FIG. **2**C is an exploded view of another exemplary self-powered portable electronic device having piezoelectric ceramic fibers to harvest mechanical energy.

[0043] FIGS. **3**A and **3**B are perspective views of exemplary piezoelectric ceramic fiber composites;

[0044] FIG. **4** shows an exemplary multilayer piezoelectric fiber composite and method of making the composite;

[0045] FIG. **5** shows an exemplary piezoelectric fiber composite for charge generation;

[0046] FIG. **6** shows an exemplary electric voltage generation by piezoceramics;

[0047] FIGS. **7**A-**7**C show several exemplary forms that a piezoelectric fiber composite may take;

[0048] FIGS. **8**A and **8**B show exemplary voltages that may be generated by the piezoelectric fibers in response to mechanical energy inputs;

[0049] FIG. **9** shows an exemplary piezoelectric ceramic fiber energy harvesting system for converting waste mechanical energy in to electrical energy or power for self-powering a feature of a portable electronic device;

[0050] FIG. **10** is a flow chart showing the generation, collection, and storage of electrical energy from mechanical energy inputs for powering a load of a portable electronic device;

[0051] FIG. **11** shows exemplary direct and converse piezoelectric effects;

[0052] FIGS. **12**A and **12**B show exemplary voltages that may be generated by the piezoelectric fibers in response to mechanical energy inputs;

[0053] FIG. **13**A shows exemplary power generation for a range of applied forces;

[0054] FIG. **13**B shows exemplary power generation for a range of frequencies;

[0055] FIG. **14**A shows exemplary resonance frequencies for a range of thickness ratios;

[0056] FIG. **14**B shows exemplary power generation for a range of thickness ratios;

[0057] FIG. **15**A shows energy produced in a self-powered transmitter being used in a sport utility vehicle on a bumpy road;

[0058] FIG. **15**B shows energy produced in a self-powered transmitter being used in a small car on a smooth road;

[0059] FIG. **16**A illustrates a bike set up to be tested; and

[0060] FIG. **16**B shows voltage produced by vibrating the bike of FIG. **16**A.